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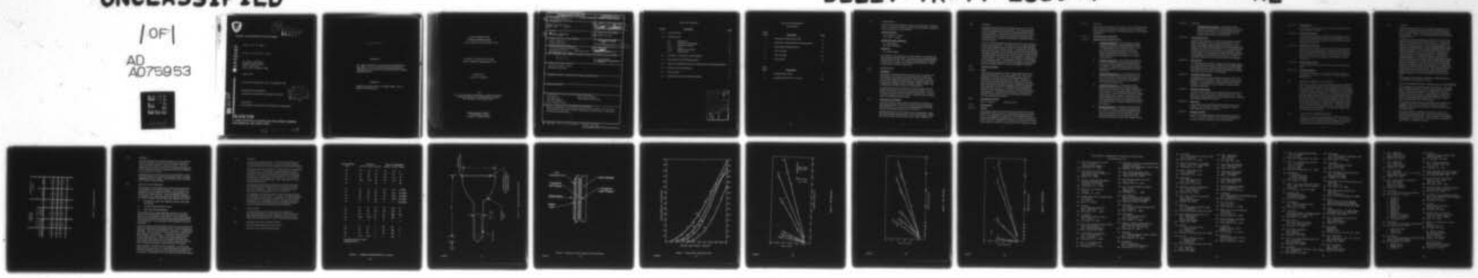

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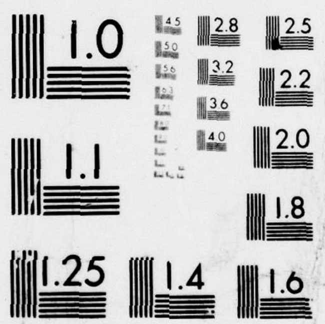

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Research and Development Technical Report

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HIGH CONTRAST CRT

Dr. Glenn A. Holmquist
Watkins-Johnson Company
440 Mt. Hermon Rd.
Scotts Valley, California 95066

August, 1979

Fourth Interim Report for 1 June - 30 September 1978

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HIGH CONTRAST CRT

FOURTH INTERIM REPORT

1 JUNE THROUGH 30 SEPTEMBER 1978

Contract No. DAAB 07-77-C-2639

File No. 672705A 1L162705AH94 D1 08

Prepared By:

Glenn A. Holmquist

For

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- Laminar Flow Electron Gun

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
Additional faceplates were fabricated; a third CRT was completed. The improved choice of glass components eliminates graded glass seals and yields a viable CRT as indicated by measured data.

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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS
AND TABLES

1.0 CONFERENCES

5 July 1978 at Watkins-Johnson Company in Scotts Valley, California. This is a report on a conference held at Watkins-Johnson Company to review the progress on this program.

Personnel Present

Mr. Norman H. Lehrer
Mr. John L. Turner

Lockheed Research Laboratory

Dr. Grant Maple
Dr. Robert Buchanan

ERADCOM

Dr. Elliott Schlam

The progress of the publication of interim reports was reviewed and time commitments were made. The exerciser was operational and a demonstration was held. Dr. Schlam indicated that some modifications be made to increase the versatility of the exerciser. These modifications are listed in Section 6.0.

2.0 INTRODUCTION

2.1 Background

Development of the high contrast two-color tube, the objective of this program, encompasses the fabrication of the screens and their assembly into the completed tube. The screens are being made by the Lockheed Palo Alto Research Laboratory under subcontract from Watkins-Johnson Company. Watkins-Johnson will assemble the completed screens into finished tubes.

The preliminary work to determine the optimum parameters for phosphor deposition on the screens has been completed. In this interim four screens are fabricated and characterized. The work on sixteen additional screens is begun. Data from three complete CRT's are determined and analyzed.

2.2 Statement of the Problem

The basic objective of this program is the ability to display information generated by various electronic systems with suitable high resolution in two colors with its legibility maintained under ambient illumination ranging from 10^4 to 10^{-3} fc.

Existing color tubes cannot satisfy the above requirement. Such tubes which employ aperture masks are severely limited in brightness and resolution by the aperture mask. Their brightness is

2.2 Continued

limited because the aperture mask transmission is only 15-20%, therefore wasting 80-85% of the current. The wide spacing between holes degrades the resolution below that required in most military systems. Furthermore, the color purity of such tubes is influenced by their position with respect to the earth's magmetic field and it is therefore impractical to incorporate them in airborne systems.

The use of color penetration phosphors overcomes some of the problems of mask type tubes. The color purity is no longer affected by the tube orientation and the resolution is higher than that which can be achieved with a mask type tube. Conventional color penetration tubes which employ powdered phosphors can not be used for daylight (high brightness) viewing because of their high reflectivity and low brightness particularly in red, which produces a washed-out low contrast display. The reflectivity of the phosphor is high because of its particulate nature. The brightness of the red is low because of most of the light generated by the red phosphor is scattered by the green phosphor before it reaches the faceplate of the CRT.

2.3 Technical Guidelines

2.3.1 Scope

These technical guidelines outline a program leading to the design and fabrication of a very high contrast CRT. The screen phosphors of this CRT are to be of the transparent film type and backed by a black light absorption coating. Therefore, a prime objective of this program is the incorporation of a phosphor-screen technology that will result in transparent film phosphors deposited on a substrate-faceplate which is an intergral part of the CRT envelope. It is furthermore intended that the phosphor screen incorporate a two layer, penetration type multicolor structure. The phosphored faceplate is to be attached to available tube envelopes in a manner consistent with economical CRT manufacturing methods.

2.3.2 Applicable Documents

MIL-E-1 Manual MIL-STD-1311A

2.3.3 Requirements

2.3.3.1 General

This program shall be directed toward the development of a high contrast CRT based on the use of high efficiency transparent phosphors. This capability is intended to be accomplished by the deposition of transparent phosphor layers on a suitable substrate that will be bonded to a standard CRT envelope in an economical manner. This program is intended to accomplish this by an extension of avail-

2.3.3.1 Continued

able phosphor techniques to CRT sizes now used in military equipment. Areas of investigation and performance will include, but not necessarily be limited to, the features outlined in the following paragraphs.

2.3.3.2 Detailed Program Objectives

2.3.3.2.1 Phosphor Screen Characteristics

1) Luminescent Material - The luminescent material shall be one that has a demonstrated high cathodoluminescent efficiency in transparent form. Since it is intended that bi-layer films be used, the demonstrated efficiency should be with various colors, particularly red and green. It is not intended that phosphor development per se, be part of this program.

2) Phosphor Persistence - The transparent phosphors used in the CRT screen should have persistence in the range of JEDEC designations "medium short" to "medium". Trade-offs of persistence with other phosphor properties and characteristics should be determined.

3) Physical Characteristics - It is intended that a bi-layer type of phosphor screen shall be used in the CRT. In that event, each phosphor layer shall be transparent and may or may not be separated by a tranparent dielectric layer.

4) Light Absorbing Layer - A requirement of this program is that the phosphor screens be backed, on the electron gun side, with a uniform light absorbing coating that can be effectively penetrated by the electron beam. Specular reflection from this coating, on the phosphor side, should be no greater than 1%. Diffuse reflectance shall be no greater than 0.25%. This coating shall not cause any substantial reduction in electron-current or electron-energy into the phosphor screen.

5) Phosphor Electrode - The phosphor electrode shall be a thin aluminum film, behind the black coating of 2.3.3.2.1-4, and electrically insulated from all other tube electrodes by means sufficient to withstand the operating levels within the tube without electrical breakdown or appreciable leakage current.

2.3.3.2.1 Continued

6) Phosphor Screen Substrate - The phosphor screen substrate shall be capable of withstanding all necessary fabrication techniques of the transparent film screen without change of shape or curvature that would degrade the end result of a completed CRT.

2.3.3.2.2 CRT Characteristics

The goal of this program is a CRT that is physically and electrically replaceable with a currently existing CRT. To this effect, the envelope, deflection angle and means, focusing means, and biasing should duplicate a Dumont KC3055 (formally KC2626) CRT used in the AN/A PR-39. It is accepted that an improved electron gun may be used with this phosphor screen. To this effect, it is desirable that the final CRT be electrically interchangeable with the KC3055, as closely as possible, so that power supplies driving the KC3055 need not be replaced.

2.3.3.2.3 CRT Contrast

It is necessary that the CRT be legible in direct sunlight under its normal mode of operation, without the use of added contrast enhancement devices. Specific quantitative criteria to satisfy this requirement should be developed so that optical instrumentation tests may be used for its verification.

2.3.3.2.4 Faceplate Characteristics

The faceplate size should be directed to the above CRT. The faceplates shall be bonded to the tube envelope by conventional means or use of graded seals. Glass-to-metal seals are undesirable. This program is not intended to support special envelope development.

2.3.3.2.5 Phosphor Voltage Range

The CRT should operate within conventional limits of anode potential. In no case should this potential exceed 20 kV. In the penetration screen configuration, anode potential shifts to achieve color changes should be minimized.

2.3.3.2.6 Resolution

A line width, taken at the half amplitude point of the spot distribution, of 0.012 inches or better is desirable. The line width should not exceed 0.016 inches.

2.3.3.2.7 Display Luminance

The CRT is to operate under ambient illumination from 10^4 to 10^{-3} fc. The CRT luminance is to be uniformly adjustable to provide satisfactory legibility under these conditions.

2.3.3.2.8 Writing Speed

A minimum writing rate of 50,000 in/sec for a single trace for all color fields is desirable.

2.3.3.2.9 Phosphor Maintenance

The transparent phosphors shall have high maintenance under normal modes of operation consistent with paragraph 2.3.3.2.3, and burn sensitivity tests shall be conducted on the screens incorporated into the CRT.

2.3.3.2.10 Reliability Consideration

Since the CRT's developed under this program are intended for tactical and airborne applications, adequate consideration must be given throughout the development program to the reliability of this tube for such environments. As an objective, the CRT should be able to pass the physical tests for CRT's specified in MIL-E-1.

2.3.3.2.11 Environmental Testing

Environmental testing of the CRT's will not be part of this program.

2.3.3.2.12 Program Emphasis

The program emphasizes the investigative areas outlined in paragraphs 2.3.3.2.1-1, 2.3.3.2.1-4, 2.3.3.2.2, 2.3.3.2.3, and 2.3.3.2.7.

3.0 TECHNICAL APPROACH (TUBE DESIGN)

Figure 1 is a schematic of the proposed high contrast multicolor CRT. The physical dimensions are identical with that of the existing CRT (Dumont KC3055). The high contrast tube will employ a Laminarflo Gun. This gun offers advantages over the crossover gun and is described in Reference 1. The phosphor screen incorporates a black backed multilayer bicolor transparent phosphor film deposited on a substrate which is bonded to the CRT funnel. The details of this screen are described further in this report. In operation, the color of the display can be controlled by selection of the beam potential. At about 10 kV, the display will be red, at 15-20 kV the display will be green. With the exception of the focus and anode potentials, the operating voltage will be the same as the existing CRT.

4.0 THE THIN FILM PHOSPHOR SCREEN

Figure 2 is a schematic representation of the two-color high contrast film to be employed in this program. As shown in the illustration, the two-color phosphor is supported on a transparent substrate which forms the faceplate of the CRT.

4.0 Continued

The green-luninescent film is immediately adjacent to the substrate. The red-luminescent film resides on top of the green one. The opaque layer is deposited on the other face of the red phosphor film. Finally, a thin conducting aluminum layer covers the opaque layer.

In operation, the red phosphor layer absorbs most or all of the electron beam energy at potentials below 10 kV. At high potentials, for example, at 20 kV, most of the electron beam is absorbed in the green phosphor. At intermediate potentials, some electrons are absorbed by both layers, depending upon the exact value of the potential. (A mathematical description of the optimum film thickness is given in the proposal). Therefore, at low beam energies, only the red phosphor is excited and the display appears red. At high beam energies, the green-luminescent material is more excited and the display appears green. Various mixtures of the two colors are obtained at intermediate values of the potential. Note that since the luminous efficiency of the red is much lower than that of the green, it is important that the red be placed closest to the electron gun to prevent color contamination of the red by the green. If the green film were closest to the gun, it would not be possible to excite the red without getting some color contamination from the green phosphor.

The operation of this screen in high ambient lighting conditions was discussed in our proposal, P-4583.

5.0 THIN FILM PHOSPHOR SCREEN FABRICATION AND MEASUREMENT

Four faceplates were completed early in the interim. 1720 glass was the substrate material. Table 1 lists the thickness of the thin films. In each case the lanthanum oxysulfide films were heat treated for 60 minutes at 870°C. This treatment is necessary to promote atomic mass transport with subsequent ordering to increase the cathodoluminescent efficiency of the film. Optical data was determined and is listed in Table 1.

The cathodoluminescent data was determined with Lockheeds demountable system and is displayed on the graph in Figure 3. Brightness was measured at the beam current of $5\mu A$ at a series of anode potentials.

The cathodoluminescent efficiency of each film varies as indicated by the spread of the data. This is to be expected as the time-temperature treatment for crystal ordering, hence efficiency improvement, is not optimized. The La_2O_2S film is sputter deposited and in "crystalline disarray".

Faceplate Number	THICKNESS Angstroms La_2O_2S Terbium Activated	La_2O_2S Europium Activated	Al	REFLECTANCE Percent Specular	Diffuse
18	8800	4100	600	6.24	1.37
19	8800	4000	1000	6.66	--
20	8800	4000	500	7.35	0.87
21	8800	4000	500	6.74	1.91

TABLE 1 - Faceplate Data #18-21

5.0 Continued

The heat treatment for complete ordering is an hour at 1050°C; however, the glass substrate would melt at this temperature. The compromize treatment is one hour at 870°C. The "crystalline disarray" varies in extent so the incomplete ordering at 870°C varies in extent with a resulting variation in film efficiencies as observed in Figure 3.

In September, the end of this interim, the subcontract on phase II became effective, the deposition of phosphor films on sixteen faceplates (1720 glass) began. The duplication of the characteristics of film #18 was pursued.

6.0 PARALLEL TUBE PROGRAM

The exerciser is an electronic system that can drive these high contrast tubes in TV modes of operation. The exerciser was completed and demonstrated full screen raster operation at 10, 15 and 18 kV screen potential. These accelerating potentials correspond to red, yellow and green color displays respectively. Dr. Schlam requested that the following modifications be made:

1) Disable the vertical scan deflection leaving a horizontal line display.

2) Provide variable intensity control.

3) Allow tube interchangeability.

The vertical scan was easily disabled; moreover, a dc power supply was to be installed to allow deflection of the horizontal line to any desired location on the screen. The variable intensity control was provided by relocating the appropriate potentiometer to the front panel. The last request is accomodated by the use of connectors.

The basic problem with the faceplate-funnel frit seal is the thermal expansion compatibility of the glasses used. Typical CRT glass is soft glass. The 1720 glass faceplate is hard glass. A graded transition flame seal is one answer. This answer is not conducive to a high yield for a production tube. A hard glass (3320) funnel was the next logical answer. Watkins-Johnson has standard 7720 (nonex) hard glass headers that are compatible with 3320 glass. The evolution of the optimum choice of glass components was complete: 1720 glass faceplates, 3320 funnels and 7720 headers.

In the meantime, the third CRT was completed. An Einzel lens laminar flow gun was used. The Einzel gun electrical requirements are most compatible with those of the monochrome tube that is to be replaced. The brightness was measured for different grid drives

6.0 Continued

for each of four anode potentials. All data was determined at a writing speed of 5000 inches per second and a 60 hertz refresh rate as described in the second triannual report (ECOM-77-2639-2).

The data for the first three CRTs is listed in Table 2 and displayed in Figures 4 to 6. The brightness is approximated as a liner function of grid drive within the scatter of points for the data for these tubes. The slope of the linear approximation will indicate the efficiency of the phosphor in the ideal case. These devices are not perfect; they are not ideal. They are in fact new, first of their kind of devices.

The gradual increase in the brightness per volt grid drive data for increasing anode potential is shown in the family of curves for CRT #2 (Figure 6). Figures 4 and 5 compare data for the three tubes at anode potentials of 10, 15, and 18 kV.

The brightness per volt drive ratio at 10 kV is greatest for CRT #3, smaller for #2 and least for #1. However, at anode potentials of 15 kV and greater this ratio is greatest for #2, smaller for #3 and least for #1. This change in order is possibly due to either a difference in the individual electron gun operating characteristics or a difference in the efficiency of the phosphor.

7.0 CONCLUSIONS

Limited condlusions can be drawn from this initial data: this approach produces a viable cathode ray tube; the maximum light output achievable (peak line brightness) is 26 fc at 10 kV anode potential (red) and 345 fc at 18 kV anode potential (green).

8.0 PROGRAM FOR NEXT INTERIM PERIOD

Complete faceplate fabrication next interim.

Fabricate CRTs with the four faceplates.

Anode Potential (kV)	Grid Drive (S/N 1)	Grid Drive (S/N 2)	Grid Drive (S/N 3)	Peak Line Brightness (S/N 1)	Peak Line Brightness (S/N 2)	Peak Line Brightness (S/N 3)
10	10	10	10	1.5	1.6	6
10	20	20	20	3.7	5.3	8.5
10	30	30	30	6.4	8.8	10
10	46.5	42.1	40	7.9	11.8	17
10	--	--	50	--	--	26
15	10	10	10	4.3	10.7	9 (14kV)
15	20	20	20	20	47.5	31 (14kV)
15	30	30	30	43	88.5	59 (14kV)
15	45	45	40	60	125.0	68 (14kV)
15	--	--	50	--	--	105 (14kV)
18	10	10	10	7.7	31.4	17
18	20	20	20	37	153	81
18	30	30	30	73	260	130
18	49.5	45.2	40	95	345	--
18	--	--	--	--	--	--
20	10	10	--	26	40	--
20	20	20	--	62	202	--
20	30	30	--	94	340	--
20	45.5	45.6	--	--	445	--

Bipotential gun S/N 1 and 2
Einzel gun S/N 3

TABLE 2 - Brightness data for CRT's #1, 2, and 3

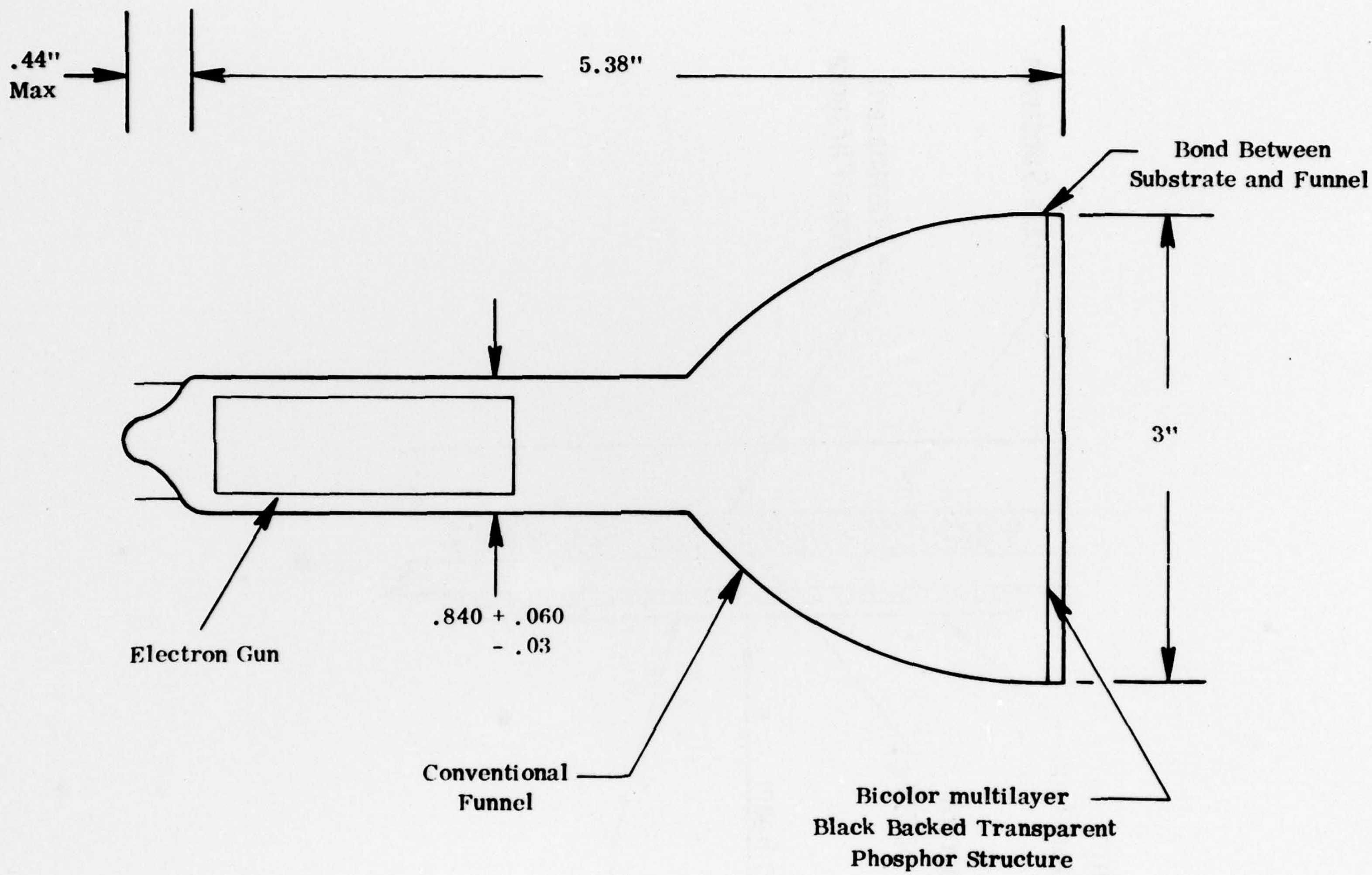

Figure 1. Schematic of High Contrast CRT

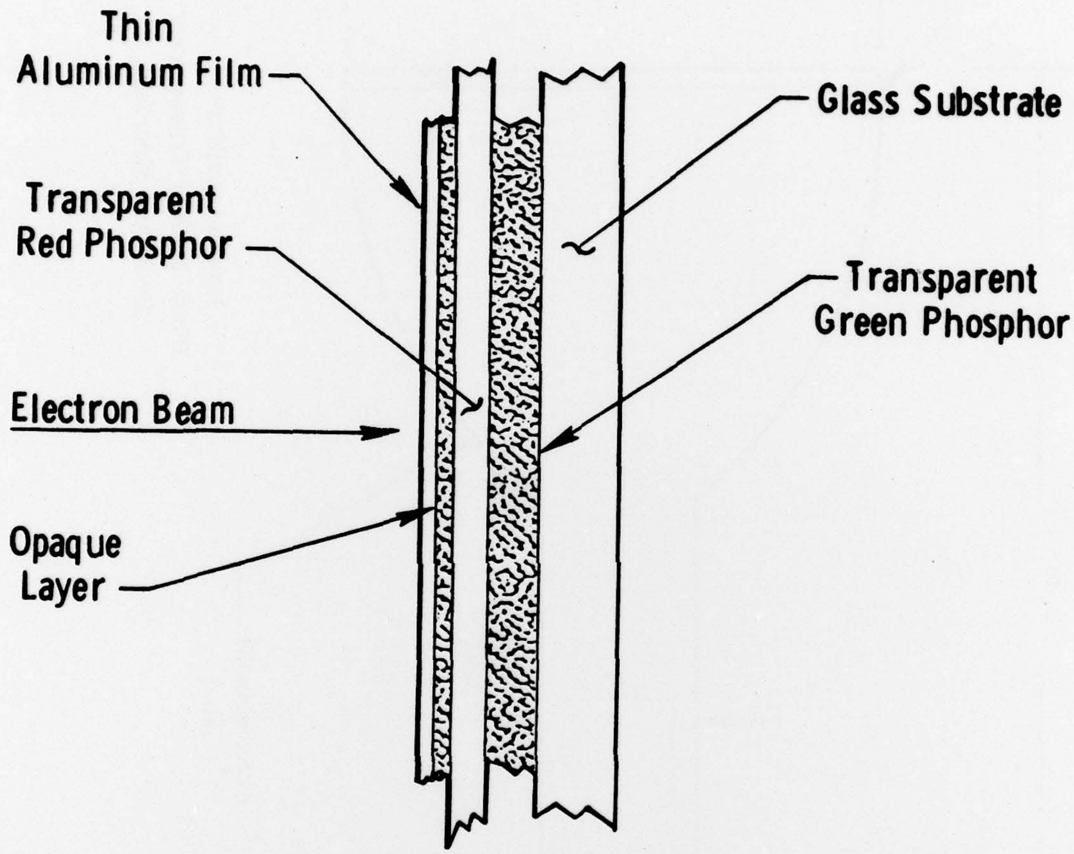

Figure 2. Schematic of High Contrast Two-Color Screen

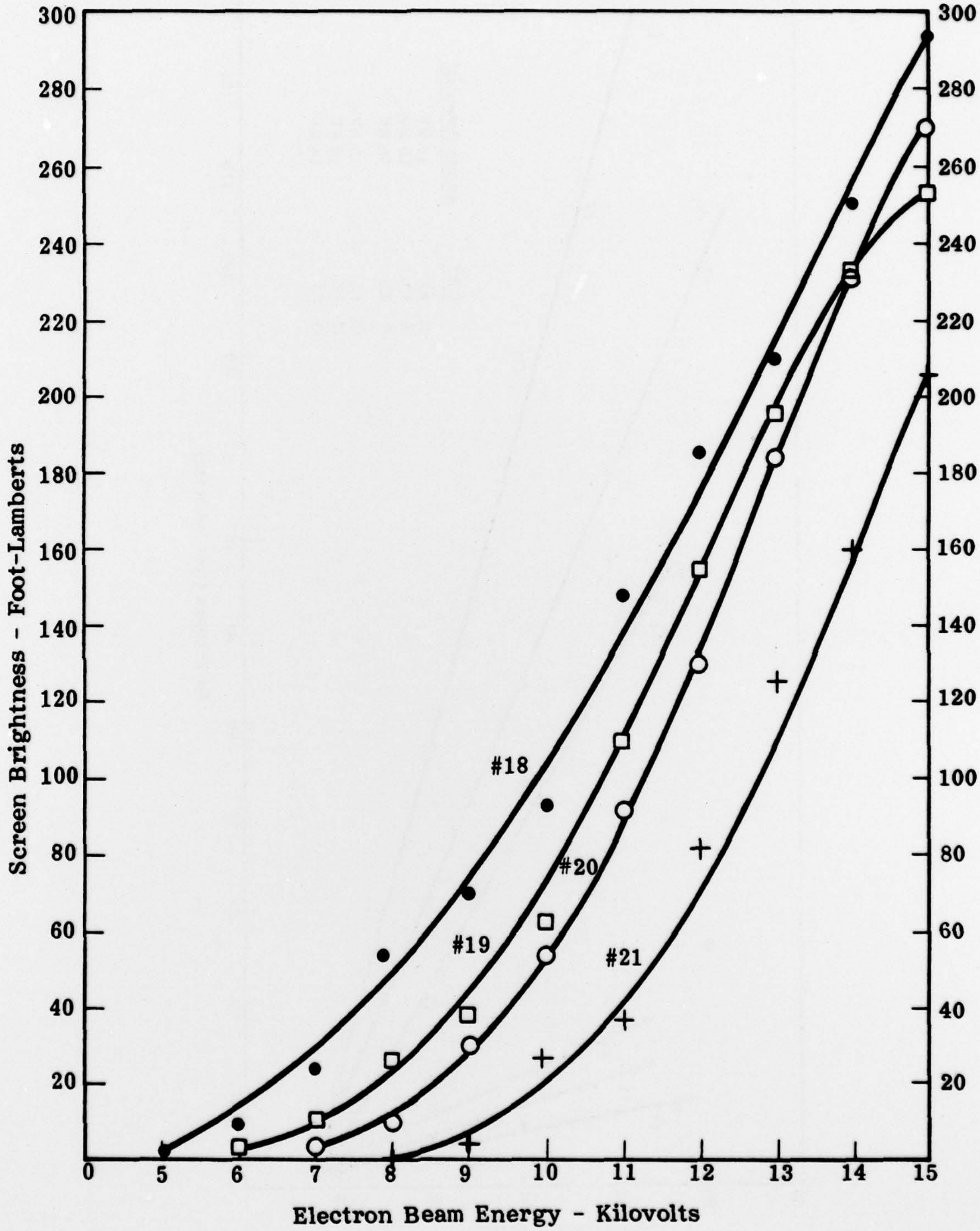

Figure 3 - Demountable Brightness Data.

aa43524

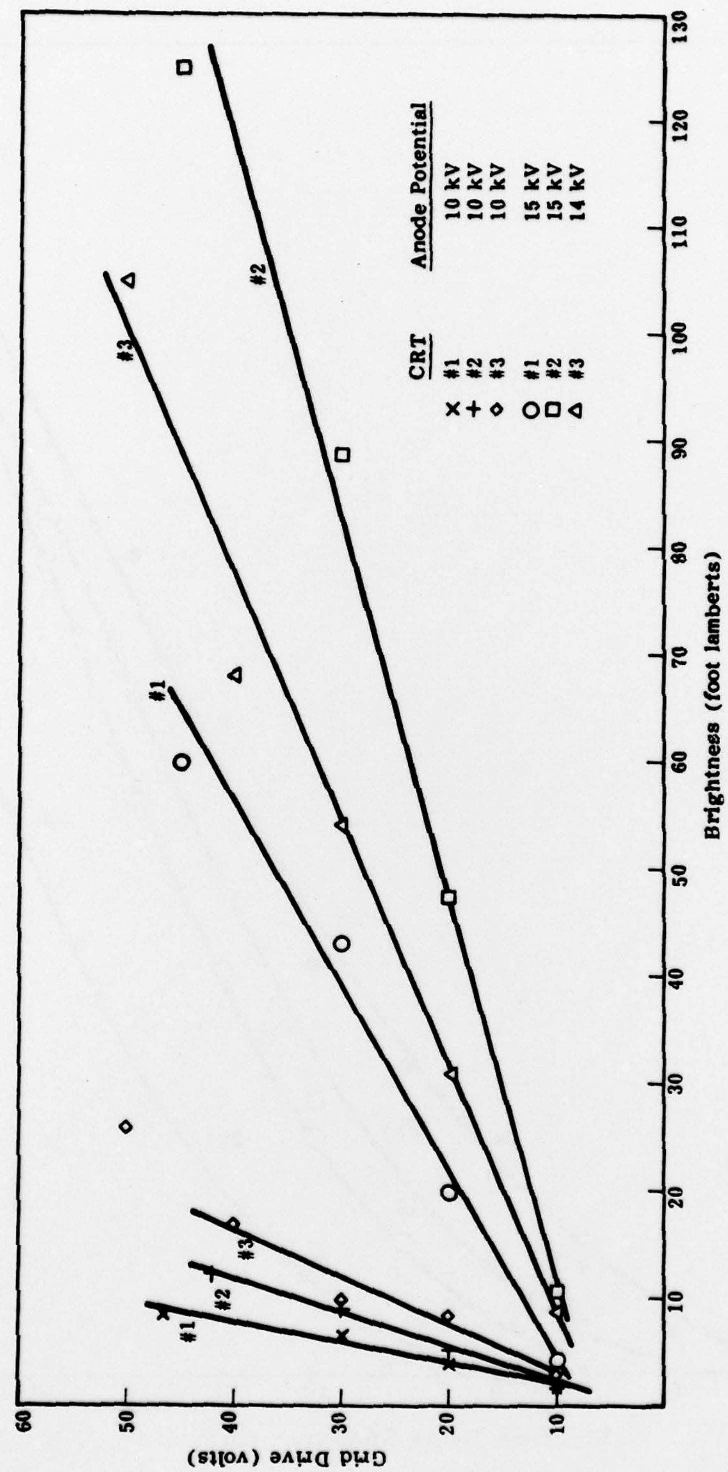

Figure 4 - CRT Test Data

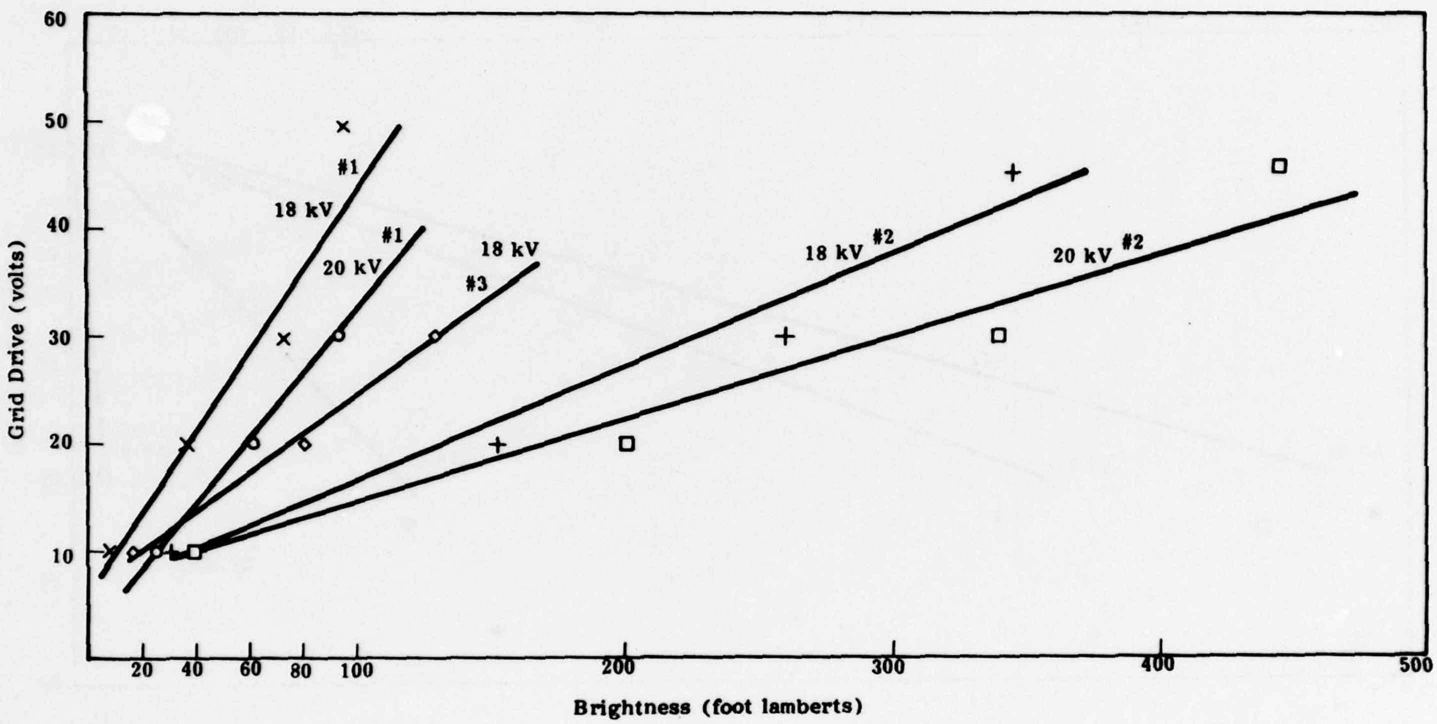

Figure 5 - CRT Test Data.

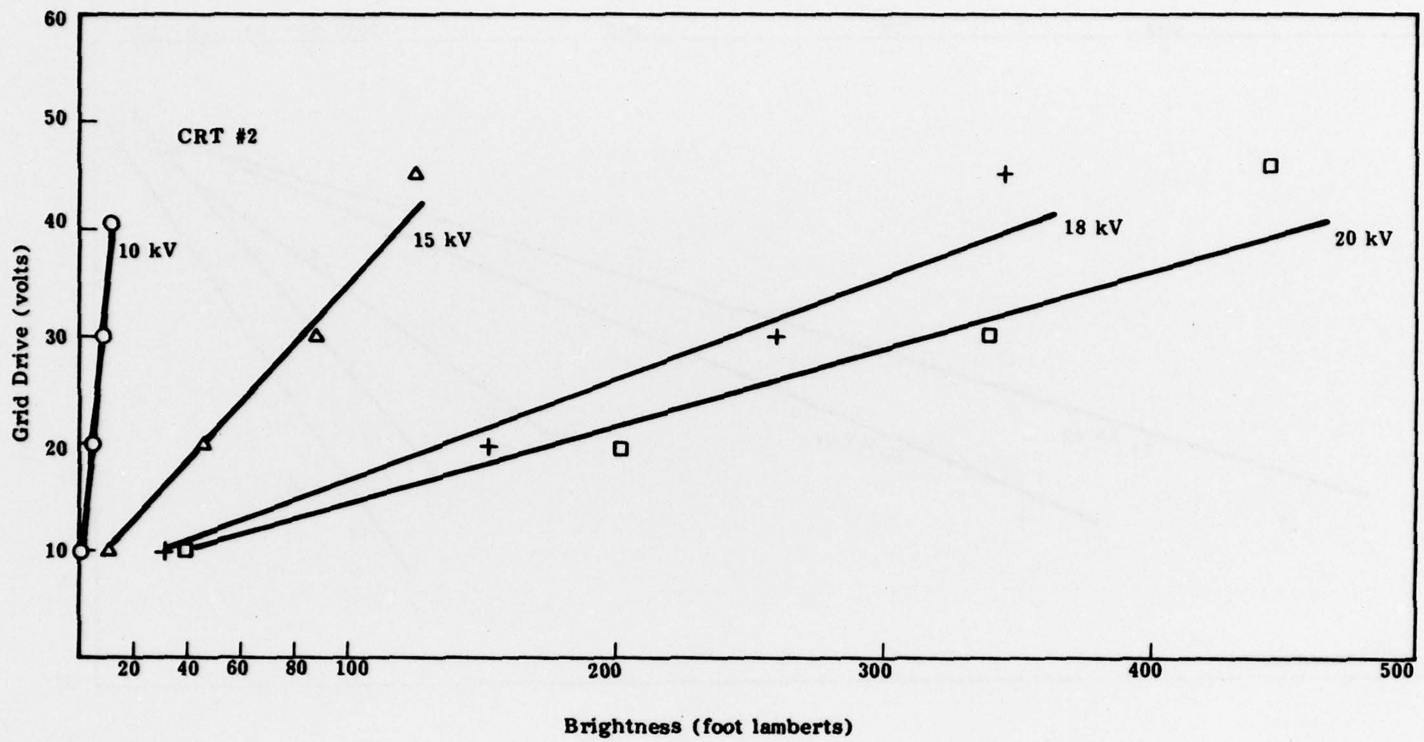

Figure 6 - CRT #2 Data.

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